Nano-Composites and Their Application in Gas Sensors

Synopsis in candidature for the degree of

Doctor of Philosophy in Physics

Submitted

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1. Introduction

Gas sensors, the devices used to detect the hazardous and toxic gases present in the environment and expelled by the chemical industries and automobile fuel combustion. The rapid industrialization of our society has made it necessary for measurement technologies for monitoring of various gasses, fumes etc to grow in parallel. At present, detection of gases became a point of necessity to control the environmental balance [1-2]. The developments of miniature and portable gas sensors that are able to detect gases in real time with good sensing performance will significantly impact our daily life [3]. In the last few years there has been an explosion in the number of published papers dealing with non-metals for gas sensor application.

1. 1. Need of Gas sensors:

There is a need for simple, sensitive and stable electronic sensors suited for trace detection in a wide spectrum of applications ranging from lab-on-a-chip and in vivo biosensors to environmental monitoring and warfare agent detection, as opposed to the often employed expensive, bulky and complicated instrumental methods. This need for inexpensive, low-power devices is fuelling the exponential growth of research in this area [4]. Researchers are trying to fabricate suitable materials that could be employed as better gas sensors with fast response, long-term stability, high sensitivity, and greater selectivity [5]. In recent years, numerous gases and volatile organic compounds (VOCs) have been utilized in large areas of industrial production and research applications as one of the reaction agents [6]. There is an important point to be concerned to control and monitor these harmful species, considering a huge risk of damage to assets and human beings if a leak occurs. There are certain gases which can be toxic for humans, and can cause big explosions. Accordingly there is a need of gas sensors with the intention of continuous and effective detection of these gases to evade predominantly the above said dangers. An ideal gas sensor should posses the following sensing properties [7]:

- High Sensitivity to certain gases
- Reversibility
- Faster response time and good recovery time.
- High Selectivity
- Long term Stability
- Simple principle of operation
- Easy to handle.
- Simple fabrication techniques.

• Temperature insensitive.

The sensitivity (S) of a sensor is determined as (ΔR/R)*100, where ΔR is the change in resistance after exposure to the target gas. S is expressed in terms of %. Selectivity refers to the characteristics that determine whether a sensor can respond selectively to a gas or a group of gases. Detection limit is the lowest concentration of the gas that can be detected by the sensor under given conditions. Response time is the time taken by the sensor to respond to a certain gas. Recovery time is the time taken by the sensor to return to its initial state after gas desorption.

1.2 Classification of Gas Sensors:

Gas sensor devices are used to detect the hazardous and toxic gases present in the environment and those expelled by the chemical automobile fuel industries and combustion. Gas sensors are the devices that are of supreme importance. A sensor comprises of a transducer and an active layer for converting the chemical information into electronic signal like resistance change, current change or voltage change. Fundamentally, conventional detection methods which construct systems that ignite an aural alarm to inform people when there is a gas seepage that is dangerous or toxic. However, it is not very consistent because it is required to get precise real-time measurements of the concentration of a gas. There are different types of gas sensors used for detection of different gases including:

1. Semiconductor gas sensors.
2. Catalytic gas sensors.
3. Electrochemical gas sensors.
4. Optical gas sensors.
5. Infrared gas sensors.

1.3. Goals:

1. This thesis aims at achieving the following goals:
2. Study the performance of GO/Metal Oxide based gas sensor at low temperatures.
3. Study the performance of GO/Metal Chalcogenides based gas sensor at low temperatures.
4. Study the performance of GO/Polymer based gas sensor at low temperatures.
5. Study of Samples prepared by microwave assisted carbonization of table sugar.
6. Study the effect of temperature and concentration of gas on the sensor.

1.4 Methodology:

Microwave synthesis of materials is fundamentally different from the conventional synthesis in terms of its heating mechanism. In a microwave oven, heat is generated within the sample volume itself by the interaction of microwaves with the material [8–10]. Microwave energy heats the material on a molecular level, which leads to uniform heating, whereas, conventional heating systems heat the material from outer surface to interior, which results into steep thermal gradients. In fact, microwave energy has became an essential tool in the processing of some of the technologically important products such as ceramic honeycombs, where thermal gradients have to be minimized in order to avoid the formation of cracks which occur during drying [11].

1.4.1 Carbonized Sugar/Metal oxide composite nanostructures

The carbonized sugar will be synthesized using above mentioned microwave assisted synthesis method. The metal oxides will be synthesized using chemical wet methods. The as prepared carbonized sugar and the metal oxide sample will be merged in different proportions to make pellets and the pellets will be employed for their gas sensor properties with basic explanations of sensing mechanism.

1.4.2 Carbonized Sugar/Metal chalcogenides composite nanostructures

The carbonized sugar will be synthesized using above mentioned microwave assisted synthesis method. The metal chalcogenides will be synthesized using chemical wet methods. The as prepared carbonized sugar and the metal chalcogenides sample will be merged in different proportions to make pellets and the pellets will be employed for their gas sensor properties with basic explanations of sensing mechanism.

1.4.3 Carbonized Sugar/Polymer composite nanostructures

The carbonized sugar will be synthesized using above mentioned microwave assisted synthesis method. The polymer will be synthesized using chemical wet methods. The as prepared carbonized sugar and the polymer sample will be merged in different proportions to make pellets and the pellets will be employed for their gas sensor properties with basic explanations of sensing mechanism.

1.5 Characterization details:

A concise account of the instruments and techniques used for acknowledgement of structural, morphological, electrical and gas sensing properties of the sensor sample, are discussed in this section.

1.5.1 Structural studies

X-ray diffraction (XRD) technique is a one of the influential, renowned and most appropriate techniques for structural revelation of materials prepared in the form of films or powders.

1.5.2 Raman Spectroscopy

Raman spectroscopy is a spectroscopic technique used to observe vibration, rotational, and other low-frequency modes in a system.

1.5.3 Fourier Transform Infrared Spectroscopy

FT-IR spectroscopy is a tool for investigation of the various chemical groups present in the sample material.

1.5.4 Morphological studies

Scanning Electron Microscopy is a tool for investigation of the surface morphology and posture of the sample material.

1.5.5 High Resolution Transmission Electron Microscopy (HR-TEM)

HR-TEM is one of most powerful techniques used in the characterization of Nanocomposites. It has capacity to inspect the constitutional characteristics of Nanocomposites such as grain shape and size, crystallinity and chemical variations at a nanometer scale resolution.

1.5.6 Gas Sensor setup

The change in resistance of the sensor, due to the presence of target gas, can be recorded by using Computer assisted 6-digit Keithley 6514 System electrometer. Keithley electrometer was coupled to the computer via RS232 interface to record the change in resistance with respect to time.

1.6 Plausible Outcomes

Fabrication of as prepared carbonized sugar/metal oxide, carbonized sugar/metal chalcogenides and carbonized sugar/polymer composites and their gas sensor application with excellent sensitivity, stability and repeatability. High index journal research articles will be published.

1.7 References:

1. Jadhav, V.V., Patil, S.A., Shinde, D.V., Waghmare, S.D., Zate, M.K., Mane, R.S. and Han, S.H., 2013. Hematite nanostructures: Morphology-mediated liquefied petroleum gas sensors. Sensors and Actuators B: Chemical, 188, pp.669-674.
2. Bhande, S.S., Mane, R.S., Ghule, A.V. and Han, S.H., 2011. A bismuth oxide nanoplate-based carbon dioxide gas sensor. Scripta Materialia, 65(12), pp.1081-1084.
3. Zhang, T., Mubeen, S., Myung, N. V., & Deshusses, M. A. (2008). Recent progress in carbon nanotube-based gas sensors. Nanotechnology, 19(33), 332001.
4. Llobet, E. (2013). Gas sensors using carbon nanomaterials: A review. Sensors and Actuators B: Chemical, 179, 32-45.
5. Sun, Y.F., Liu, S.B., Meng, F.L., Liu, J.Y., Jin, Z., Kong, L.T. and Liu, J.H., 2012. Metal oxide nanostructures and their gas sensing properties: a review. Sensors, 12(3), pp.2610-2631.
6. Nguyen, H. and El-Safty, S.A., 2011. Meso-and macroporous Co3O4 nanorods for effective VOC gas sensors. The Journal of Physical Chemistry C, 115(17), pp.8466-8474.
7. Yamazoe, N., 2005. Toward innovations of gas sensor technology. Sensors and Actuators B: Chemical, 108(1), pp.2-14.
8. Mani, G.K. and Rayappan, J.B.B., 2013. A highly selective room temperature ammonia sensor using spray deposited zinc oxide thin film. Sensors and Actuators B: Chemical, 183, pp.459-466.
9. Istas J.R., de Borger, R., de Temmerman, L., Guns, K., Meeus Verdinne, A. Ronse, P. Scokart, Termonia, M., 1988. Effect of ammonia on the acidification of the environment, European Communities Report No. EUR 11857 EN,
10. Warneck, P., 1998. Chemistry of the Natural Atmosphere, Academic Press Inc.,
11. D. Nicolas-Debarnot, F., (2003). Poncin-Epaillard, Polyaniline as a new sensitive layer for gas sensors, Review, Anal. Chim. Acta 475 1–15.

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